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Task Y-R011-01-052

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INVESTIGATION OF SCALE REMOVAL FROM THE EXTERIOR OF  
HORIZONTAL TUBES EVAPORATING A THIN FILM OF SEA WATER

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**INVESTIGATION OF SCALE REMOVAL FROM THE EXTERIOR OF HORIZONTAL TUBES  
EVAPORATING A THIN FILM OF SEA WATER**

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**ABSTRACT**

The purpose of this test was to investigate scaling in horizontal tube, spray type evaporators that have high heat transfer coefficients. These evaporators employ circulation through spray nozzles which produce a falling film over heating surfaces.

The test consisted of the intermittent operation of an evaporator which was modified from a used heat exchanger. Heat was supplied from low pressure steam. Scale formation was observed visually through a window in the unit. Before the test was concluded, the unit was treated with sulfuric acid to remove the scale.

It was concluded that this type of evaporator had scale problems very similar to conventional type evaporators and that the same type of scale control treatment is effective.

## INTRODUCTION

The formation of scale in vapor compression type sea water distillation units has always been a problem. In past studies at this Laboratory, it has been found that frequent, periodic injections of acid almost eliminated the formation of scale in conventional type vertical tube evaporators that are used on vapor compression units.<sup>1</sup>

The purpose of this test was to investigate the formation of scale in a horizontal tube evaporator in which sea water is sprayed to produce a film over the outside of steam heated tubes. This type of evaporator is potentially suitable for use on vapor compression stills because the thin film results in high heat transfer coefficients.

## DESCRIPTION OF EQUIPMENT

The equipment used for this task consists of an evaporator, circulation pump, feed pump, float control valve, automatic steam temperature control valve, and associated pieces of hardware.

The evaporator was a used heat exchanger that was modified slightly and consists of an insulated rectangular steel box, approximately 73 inches long by 14 inches wide by 25 inches high. It has 52 1-inch diameter 18 gauge steel tubes running horizontally lengthwise through it. The tubes, arranged in a triangular pattern, occupy the lower 13 inches of the unit. They extend into headers on each end which are baffled to form a 2-pass heat exchanger. These tubes provide approximately 82 sq. ft. of heating surface. Two spray nozzles were located approximately 8 inches above the top of the tubes at each end of the evaporator. (See Figure 1.) An 8-inch diameter window was installed in the side of the unit, with its centerline level with the top of the tubes.

The feed pump and circulation pump were located directly below the evaporator.

Sea water was fed through the float control valve, which maintained a water level about 1.5 inches above the bottom of the evaporator. The water was then gravity fed from this reservoir to the circulation pump which fed the spray nozzles at 15 psig and 13 gpm. Brine was discharged from this circulation line at approximately .24 to .36 gpm, which was from 64 to 90 percent of the distilled water production. The spray nozzles produced a continuous supply of water which formed a falling film over the tubes.

The tubes were supplied with steam through the temperature control valve which was set to close at 243 F. However, the temperature range during the test was from 232 to 236 F. Steam condensate was discharged at the bottom of the unit through a steam trap.

Water vapor passed through a demister on top of the evaporator, which separated water droplets from the vapor, and into a sea water cooled condenser. This condenser was located adjacent to the evaporator and was cooled by water from the sea water feed pump.

#### TEST PROCEDURE AND RESULTS

The evaporator was operated intermittently for a total of 170 hours, at an average of 5.5 hours each day.

Scale was first observed after about 70 hours of operation. At this time, an attempt was made to secure a sample of the scale to determine its composition. However, the steel tubes were rusty and the scale too thin to permit sampling. Steam temperature had increased from 232 to 234.5 F and the water production had dropped from 24.3 gph to 21.5 gph; a reduction of about 11.5 percent.

After 134.5 hours of operation, steam temperature and pressure had risen to 236 F and water production had dropped to about 19.4 gph. Another attempt was made to secure a sample of scale; however, due to increased rusting of the tubes, it was unsuccessful.

It was then decided to acid treat the unit, in an attempt to dissolve the scale. The following day the unit was started and run for about 2 hours before adding 300 ml (milliliters) of sulfuric acid ( $\text{H}_2\text{SO}_4$ ) which was 50 percent concentrated  $\text{H}_2\text{SO}_4$  and 50 percent distilled water by volume. This acid was injected directly into the evaporator reservoir. By pH measurements, it was possible to determine the length of time before the acid was neutralized. The pH dropped immediately from a normal of about pH 8 to about pH 2 and after 21 minutes had risen to pH 7. One hour later, the distilled water production had increased 14.4 percent to approximately 22.2 gph without noticeable changes in steam pressure and temperature.

At 167.5 hours of operation, 200 ml of  $\text{H}_2\text{SO}_4$  (50/50 by volume) was added to the unit. The pH dropped as before and after 24 minutes had returned to neutral. At 168 hours, another 200 ml of  $\text{H}_2\text{SO}_4$  was added to the unit. This time, it required 42 minutes to neutralize, indicating that the scale that is soluble in  $\text{H}_2\text{SO}_4$  had been mostly dissolved. The change in water production was negligible.

The test was ended after 170 hours of operation.

## OBSERVATIONS DURING TESTING

1. After the first acid treatment, the tubes appeared to be completely free of scale except for rust, and remained that way throughout the rest of the test.

2. The distilled water produced by the unit contained between 8 and 14 ppm (parts per million by weight) of dissolved solids and did not vary with production.

3. The pH of the blowdown normally ranged from 7.9 to 8.85. The blowdown contained from 66,700 to 90,000 ppm of dissolved solids.

## CONCLUSIONS

It appears that thin film spray type evaporators which may be adaptable for use on vapor compression distillation units will have the same problems with scale formation as do conventional type vertical tube evaporators. However, it appears that the same type of scale control treatment is effective; namely, daily acid treatment with the unit in operation.

## REFERENCES

1. NCEL Technical Report R-011. Acid Injection Prevents Scale in Vapor Compression Distillation Units, by J. S. Williams. Port Hueneme, California, 20 December 1958.

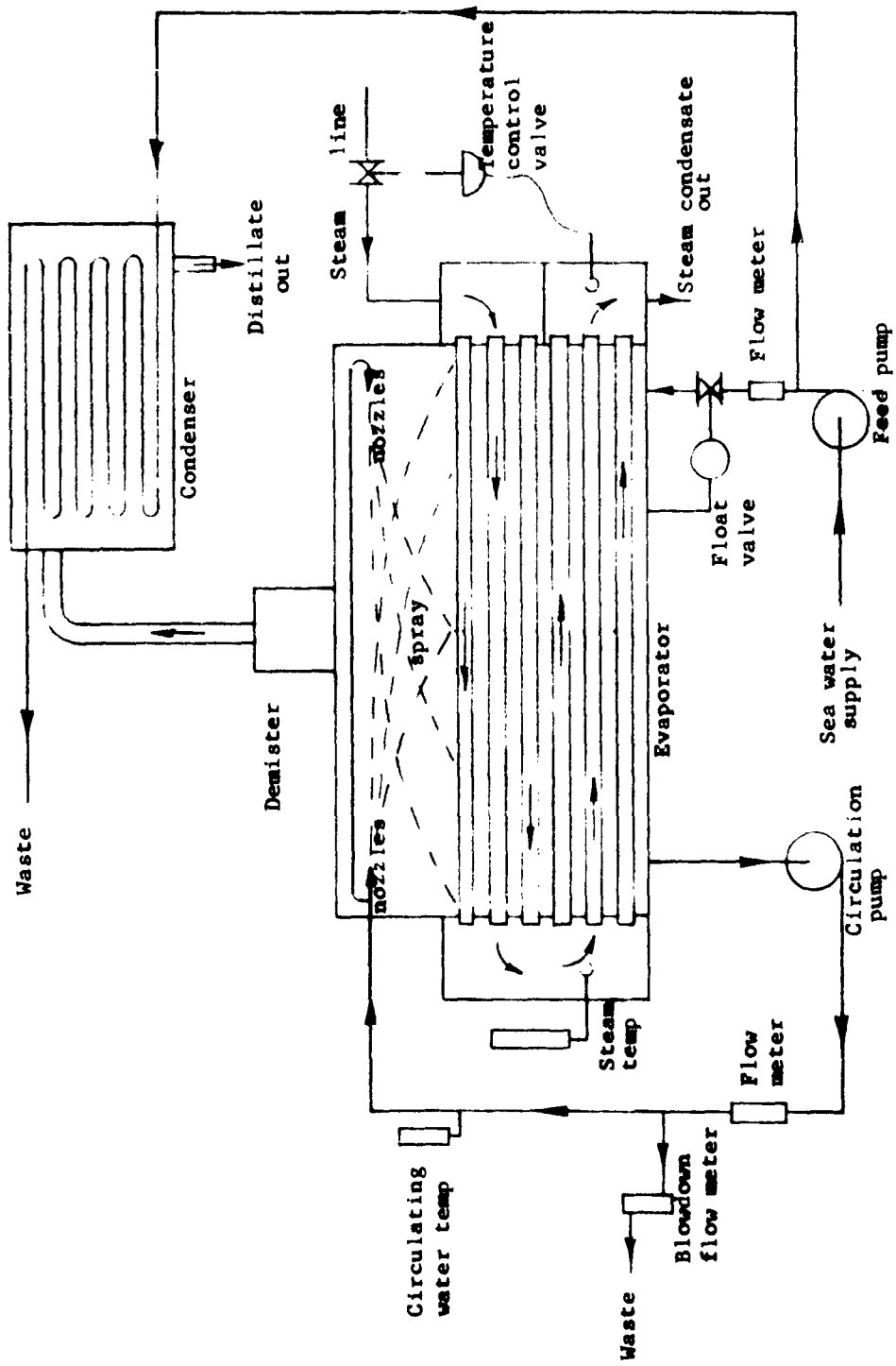


Figure 1. Test apparatus